GLOBAL PERSPECTIVES ON HIGHER EDUCATION

# University and Development in Latin America

## Successful Experiences of Research Centers

Simon Schwartzman (Ed.)

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# THE LEADING LATIN AMERICAN UNIVERSITIES AND THEIR CONTRIBUTION TO SUSTAINABLE DEVELOPMENT IN THE REGION

## INTRODUCTION

This book is based on the experiences of sixteen university research groups in four Latin American countries – Argentina, Brazil, Chile, Mexico - from different fields of knowledge, working in very different national contexts, but sharing the experience of producing high quality scientific knowledge in their fields, and, at the same time, being very active in transferring their knowledge to society. They are not typical of the usual academic centers in the their own countries, which work in accordance with research agendas established by their individual members, with subsidies from the education or science and technology authorities, and, even when working in applied fields, have difficulties or give low priority to making their competencies available to business, governments and public agencies that could put them to practical use. We believe, however, that they point to the future.

Science-based knowledge is essential for creating wealth, caring for the environment, improving health, and dealing with the social problems of poverty, urban overcrowding and social violence. It is not possible to expect scientific research in the region to mature first, and then start bearing fruit to society. As in the economy, the social benefits of accumulation cannot be postponed forever, and Latin American societies are not likely to put more resources in to their scientific establishments if they do not see the concrete benefits of their work. However, there are reasons to believe that this dilemma is false: knowledge creation and applications do not necessarily take place in sequence, and the best scientific institutions are those that can do both. In so doing, they attract additional resources, the best talent and, in time, overtake the institutions and groups that remain in isolation.

In developed economies, most technological research and development takes place in private companies as well as in government owned civilian and military research institutes. However, research universities are unique in their ability to attract and educate talented researchers and work at the edge of scientific research, and there is a growing trend, from private corporations, to develop strategic partnerships with universities. Japan and South Korea are examples of countries that developed strong technological capabilities in their large private corporations before developing their research universities, but, more recently, they began feeling the need to upgrade their best universities to the standards of their American and European counterparts, with India and China working to catch up (Altbach and

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Balán 2007; Indiresan 2007; Kim and Nam 2007; Liu 2007; Yonezawa 2003). In Latin America, however, most research is academic, takes place in selected departments and institutes within universities that are mostly geared to undergraduate and professional education, and with weak links to the broader economy and society.

To create these links, several countries are introducing legislation and making institutional innovations of different kinds, while, at the same time, many research teams and institutes are finding their own ways to link out and develop their innovation capability. These are, according to Judith Sutz (Sutz 2000), the ¨top-down¨ and the ¨bottom-up¨ approaches, and, in her work, she finds that "the results of the top-down mechanisms have been well below expectations of policy makers", while "bottom-up experiences usually exhibit successful results at micro level, but face great difficulties for broadening the impact of the technical solutions found". An appropriate institutional environment is necessary to spur and consolidate university science-based innovation (Hollingsworth 2000), but a precondition is the existence of a strong culture of innovation and academic entrepreneurship as a basis, and that is exactly what this study seeks to show.

In selecting the cases, we sought to cover a variety of academic fields, including mathematics, technology, biological sciences, agricultural research and the social sciences, both in public and private institutions[1]. We did not include non-academic research centers, but included some non-university institutions that are also involved in graduate education. Our unit of analysis is not the university, or even the department or institute, but a research center or group[2], which may or may not correspond to a formal administrative unit within their institutions. With these criteria, and after consultations with experts in each country, we completed our list. Several other research teams could have been selected instead of the ones we choose, but we expect that the ones we have are a good sample of this new type of research work.

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## THE IMPORTANCE OF SCIENCE-BASED KNOWLEDGE FOR SUSTAINABLE DEVELOPMENT

Contemporary societies are often described as "knowledge societies". Economic, social, cultural, and all other human activities become dependent on a huge volume of knowledge and information. The knowledge economy is based on the development of sophisticated and knowledge intensive products for the world markets, and increasing competition among countries and multinational corporations, based on their scientific and technological prowess. The importance of science-based knowledge, however, is not limited to its impact on the business sector. Issues like environment protection, climate change, security, preventive health care, poverty, job creation, social equity, general education, urban decay and violence, depend on advanced knowledge to be properly understood and translated into effective policy making practices. These needs are urgent, and countries should not have the excuse of not making use of the best possible knowledge to deal with their economic and social

questions, aiming at what is commonly understood by "sustainable development" (Serageldin 1998). Even if the economy is not very well developed, and the education institutions are of poor quality, as many of them are in Latin America, there is almost always some space for scientific competence to develop, not necessarily at a very high cost.

| | Cases in the study | | | |
|---|---|---|---|---|
| | **Biology and Environmental Sciences** | **Technology** | **Agricutural Science and Aquaculture** | **Social sciences** |
| **Argentina** | Instituto de Investigaciones en Ingeniería Genética y Biología Molecular (INGEBI)- Universidad de Buenos Aires | Área de Investigación y Desarrollo del Instituto Tecnológico de Buenos Aires | Instituto de Investigaciones fisiológicas y ecológicas vinculadas a la agricultura (IFEVA) -UBA | Departamento de Economía- Universidad Nacional de La Plata |
| **Brazil** | Departamento de Informática Univ Católica Rio de Janeiro | Instituto de Química, Universidade de Campinas | Escola Superior de Agronomia Luiz de Queiroz USP | Escola de Pós Graduação em Economia da Fundação Getúlio Vargas, Rio de Janeiro |
| **Chile** | Centro Universitario Internacional Europa América Latina (EULA). Universidad de Concepción | Centro de Modelamiento Matemático, Universidad de Chile | Centro Costero de Acuicultura y de Investigaciones Marinas. Universidad Católica del Norte | Centro de Investigación Jurídica, Universidad Diego Portales |
| **Mexico** | Instituto de Biotecnología de la Universidad Nacional Autónoma de México, Cuernavaca | Física Aplicada y Tecnología Avanzada (CFATA) de la Universidad Nacional Autónoma de México (UNAM) | Centro de Investigación y de Estudios Avanzados del IPN, CINVESTAV Unidad Irapuato | Centro de Estudios Económicos, El Colegio de México A. C. |

This belief has been clearly expressed by leading Latin American scientists who participated in the virtual forum on "Civil Society on Science, Technology and Innovation" held by the Organization of American States in 2005. This document states, among other points that:

> Cutting edge science can be produced under economically disadvantaged circumstances; scientific development, job creation and the fight against poverty are interrelated. The introduction of science, technology, engineering and innovation in our local and specific conditions, as has happened elsewhere, can determine equitable development. Information on successful cases where Science, Technology, Innovation and Science Education (STISE) have impacted on the fight against poverty, helped to create jobs and strengthened democratic governance is essential. Information and understanding of the international frameworks related to intellectual property rights and patents in all levels of society is essential, both to protect local ethnic culture, history, biodiversity and to make local inventions economically and socially useful to local society *(Organization of American States 2005).*

The challenge to improve the quality of academic research in Latin America and to make it more relevant for society is daunting. Academic and scientific institutions are complex, heavy and multi-purpose, and cannot be easily steered. In this study, we look at four among the most developed countries in Latin America – Argentina, Brazil, Chile and Mexico -, which, in different ways, have created significant higher education and scientific institutions. For many years, these countries have worked to develop their scientific and technological capabilities, in universities and specially designed Research and Development (R&D) institutions, under the assumption that modern Science and Technology (S&T) is an essential ingredient for the development of their societies from all points of view. There have been many instances of significant achievements, but also many failures, and the general view is that these efforts were not as successful as they should have been. Given the dramatic increase in investments in science and technology in the developed world, there is a strong sense that the gap is increasing. Furthermore, the recent success of some Asian countries – particularly Korea, Taiwan, China and Singapore – in closing this gap, has led to a renewed concern about the need to look again at what is happening in Latin America that is precluding similar achievements.

## HIGHER EDUCATION AND SCIENTIFIC RESEARCH IN LATIN AMERICA

Higher education institutions have always played important roles in cultivating knowledge and putting it to the benefit of society. In different times and societies, these knowledge-producing activities have ranged from traditional education in the learned professions to the development of advanced research in the basic sciences and its applications. Traditionally, higher education and scientific institutions have existed separately, and the integration of science and higher education, which is often taken for granted, is in fact a very recent phenomenon, more typical of the Anglo-Saxon countries than of elsewhere, and justified by a mythical model of academic research attributed originally to the Humboldt University in Germany. In fact, the unification of knowledge and education proposed by Humboldt was closer to the philosophical concept of *Bildung* than to the modern notion of scientific research. As scientific research developed in Germany in the second half of the 19$^{th}$ century, it moved away from the universities, and was organized later in a different institutional setting, the Kaiser-Wilhelm-Gesellschaft, now the Max Planck Institutes (Nybom 2007). In most countries, as in Germany, science, technology and universities developed and organized separately. The extreme example in the 20th century was, perhaps, the Soviet Union, with the sharp separation between the Academy of Sciences and the higher education institutions, a model copied by China and other countries of the Soviet block. This separation has also been notorious in France, with the *Centre Nationale de la Recherche Scientifique*, CNRS, bringing together the research community apart from the prestigious *grandes écoles* and the universities (Clark 1995).

The most important exception was the American graduate schools, which provided for the systematic and large-scale education of research scientists and opened space in the universities for their laboratories, an innovation justified by the Humboldtian ideal, in what Thorsten Nybom described as “one of the most

successful and productive misunderstandings in modern intellectual history" (Ben-David 1977; Flexner 1968; Geiger 1986; Nybom 2007). The success of the American research universities, which attracted students from all over the world after the Second World War, and the sheer presence of the United States as the world's leading economy, led to the gradual spreading of elements of this institutional model to most of the world, adapted to local circumstances. This dissemination was sometimes quicker in developing countries, which depended on US agencies and its philanthropic foundations for technical assistance and support, than in European countries, with their own strong traditions and institutions. Already in the 1920, the Rockefeller Foundation was actively supporting medical research in Argentina, Chile, Brazil, Mexico and Colombia, among others (Abel 1995; Coleman and Court 1993; Cueto 1990; Cueto 1994; Díaz, Texera and Vessuri 1983; Schwartzman 1991; Solorzano 1996); the Ford Foundation was very influential in establishing economics, political science and other subjects as academic disciplines in several countries (Bell 1971). The United States Agency for International Development, USAID, helped to organize agricultural research in many places (Sanders et al. 1989), and also in the reorganization of Brazilian higher education in the 1960s, with the introduction of graduate education and research departments and institutes in the universities (Botelho 1999; Sucupira 1972).

Some of these initiatives were successful, but never to the point of changing the Latin American universities at their core. Higher education developed in the region, since the 19th century, inspired by the French model, first as training and certification institutions for the learned professions (Law, Medicine, Engineering) under strict state supervision, and later, already in the 20th century, as a mobility channel for the upper segments of a growing urban middle class. Some countries, like Argentina and Mexico, created very large, semi-autonomous, public national universities, with hundreds of thousands of students, heavily immersed in national politics, in which research, when it existed, took place in small, protected niches in medical and engineering schools, and, more recently, in American-style, semi-autonomous research institutes and departments. In other countries, such as Brazil and Chile, higher education spread among a large number of smaller, public and private institutions, in which, again, education for the professions, not organized research, was the driving force (Brunner 1987; Levy 1980; Levy 1986; Schwartzman 1996).

## THE EXPANSION OF HIGHER EDUCATION

At the end of the 20th century, Latin America had to cope with the combination of an expanded, massive higher education sector, and a new vision of the way scientific and technological research should be organized to face the new challenges of the knowledge society. In 2003, the Gross Enrolment ratio in tertiary education was already 60% in Argentina, 22.7 in Brazil, 46.2% in Chile, and 23.9% in Mexico. In the whole Latin American and Caribbean region, it was 27%, compared with 69% in Western Europe and North America, and 51% in Central and Eastern Europe. At first glance, one could think that this massive expansion of enrolment was an appropriate response to the growing needs and requirements of the knowledge

society. However, this expansion was associated to several important problems which amounted, according to a comparative study carried on in the 1990s, to a serious crisis, characterized by a lack of coordination between sectors and institutions, institutional paralysis, low quality, and severe financial problems, associated both to lack of resources and their improper and inefficient use (Brunner et al. 1994). Different policies were attempted by countries to deal with this crisis, including profound changes in the financing mechanisms of higher education and the establishment of quality assessment systems. An important component of these policies have been the creation or strengthening of assessment and reward systems based on academic excellence. International organizations also contributed with their proposals for reform (Castro and Levy 2000; De Ferranti et al. 2002; Inter-American Development Bank 1997; UNESCO 1995; World Bank 2002).

## THE NEW PRODUCTION OF KNOWLEDGE

In 1994, the publication of *The New Production of Knowledge*, by Michael Gibbons and others (Gibbons et al. 1994), opened up a wide debate, still continuing, on the adequacy of the way scientific and technological knowledge production should be organized in universities and other research institutions. The book compared two modes of knowledge production, labeled "mode 1" and "mode 2", the first academic, investigator-initiated and discipline-based, and the second context-driven, problem-focused and interdisciplinary. In mode 1, research institutions are autonomous, academic rewards are associated with publications in open literature, and knowledge production follows a linear pattern, from basic to applied science, and then to development and production. In mode 2, research institutions are closely associated or linked with users – companies, government agencies, service providers, compounding what was later called "the triple helix" (Etzkowitz and Leydesdorff 1997); rewards are based on actual or expected practical products; research outcomes are proprietary; and the linear production sequence is broken, with knowledge being developed in the context of applications. In a famous paper, Donald Stokes used the term "Pasteur's quadrant" to refer to the combination of fundamental and applied research which characterized both Pasteur's 19$^{th}$ century science and the new models of scientific innovation, in contrast to "Bohr's quadrant" of basic science, an early 20$^{th}$ century development. (Stokes 1997). In a classic paper, Joseph Ben-David and S. Katz showed how agricultural research in Israel, which started with strong links with the efforts to develop agriculture in the new country, later drifted towards an academic mode, choosing their topics and reference groups in the international scientific community, and losing its applied links (Ben-David and Katz 1975). Thus, as many commentators have noted, academic research was never fully organized in accordance with "mode I", while applied, context-based and multidisciplinary research is not a recent invention (Fuller 2000; Shinn 2002). But the book helped to make explicit a tension that existed within academic research in the advanced economies, and lent legitimacy to a different approach to science policy and academic management and organization.

This tension has always been present in Latin America, even if not as explicitly as it is today. Since the 1940s and 1950s, inspired mostly by the achievements and

promises of nuclear physics, many scientists in the region had hoped that their universities could be transformed to place science and technology at their core, as part of a much broader social and economic revolution in their societies. (Herrera 1970; Klimovsky 1975; Lopes 1969; Nye 1975; Varsavsky 1971). They tended to share the political philosophy of the British and French scientific socialists, J. D. Bernal and Jean Perrin, and differed from those, more in line with the ideas of Michael Polanyi and Robert K. Merton, that had argued for a more detached, community-based, "pure" model of scientific organization, such as the mathematician Amoroso Costa in Brazil (Amoroso Costa 1971; Bernal 1967; Merton 1973; Perrin 1948; Polanyi 1947; Polanyi 1997; Ranc 1945).They were very influential and supportive of the creation of national science and technology councils and agencies.[3] All these institutions have, in their mission, the goal to support science and technology in very broad terms and put it to the service of society, and, to different degrees, created administrative and financial mechanisms to support and facilitate the bridges between science and society.

In the 1980s and 1990s, the belief that science and technology should be integrated in a comprehensive planning system for the management of society, shared both by the socialist scientists and the nationalist military, was replaced by the notion that science, technology, government and industry should be linked by complex, multi-institutional innovation systems that existed as a matter of course in the developed economies, but were mostly absent in Latin America (Branscomb and Keller 1998; Cassiolato, Lastres and Maciel 2003; De la Mothe and Foray 2001; Jones-Evans et al. 1999; Krauskopf, Krauskopf and Méndez 2007; Melo 2001). The concept of "innovation", as applied to the field of science and technology, comes mostly from economists, concerned with the ways to make companies and countries more efficient and productive in a competitive environment, and led the creation of a large array of new institutional and financial mechanisms to stimulate businesses to reach out to universities for support. In several universities, it led to the creation of offices for technical assistance and the management of intellectual property, as well as new institutional arrangements such as incubators and science parks. It also led to broader policy recommendations for changes in the national science and technology policies that, however, were seldom implemented (Schwartzman et al. 1995a; Schwartzman et al. 1995b; Schwartzman et al. 1995c)

## EXPECTATIONS AND OBSTACLES FOR THE STRENGTHENING OF THE LINKS BETWEEN UNIVERSITIES, INDUSTRIES, GOVERNMENT AND SOCIETY

So far, and with the caveat that many of these initiatives are still emerging and ongoing, these policies and institutional innovations have been less successful than what one would expect. To reach outside their walls and link with society, academic research centers and institutes need to compete with the demands of mass higher education, and also with the "mode 1" culture they have developed to support their research activities. They have to deal also with the limited demand for locally generated knowledge-based information and technology in their societies, both from industries and governments. Combined, these two factors have limited their ability to place their capabilities at the service of their societies.

In the mass higher education systems in Latin America, academic researchers are a smaller segment of a much larger academic profession, which also includes traditional professors, part-time lecturers, and a growing number of teaching, unionized and demanding university employees (Altbach 1996; Balbachevsky and Quinteiro 2002; Schwartzman and Balbachevsky 1994). The career patterns, teaching loads, resource allocation and priorities in higher education institutions are not geared to the values and expectations of the researchers, but to these broader constituencies, which also include very vocal, active and politically connected student associations

Education authorities spend their limited resources supporting the on-going activities of higher education institutions, while research agencies tend to work, typically, with grants that are provided project by project. This creates a competitive environment that is accessible to scientists with strong scientific qualifications, but not to other members of the academic profession. To make sure that the resources for science and technology are not lost in the support of routine teaching and practical activities of low scientific and technological content, scientists stress the need for peer review, international quality standards and the use of publication indicators and track records as the main criteria for selecting projects and distributing resources. They view with mistrust the use of non-scientific criteria, such as social or economic relevance, as the basis for project evaluation, as well as the participation of non-scientists in the evaluation committees and boards.

This drive in support of high-quality research has led to the establishment of quality assurance institutions that have provided support and visibility to a significant number of high quality, research oriented university departments and institutes in the different countries. The best known example is CAPES (Comissão de Avaliação de Pessoal de Nível Superior), the Brazilian agency for assessing higher education in Brazil, which, for several decades, has maintained a successful mechanism for peer-review assessment of Brazil's graduate education programs, the largest in the region (Castro and Soares 1986). CONEAU, the Comisión Nacional de Evaluación y Acreditación Universitaria, in Argentina, and the Padrón Nacional de Posgrado (PNP) in México, play similar roles.

There is also a downside, however. The resources allocated to these agencies tend to be small, and just a fraction of what the countries spend on research and technology, and innovation (Schwartzman 2002); the money tends to be scattered over a large number of small projects, since these peer-review agencies have difficulty in establishing priorities and concentrating resources; and the assumption that good quality research will eventually be transformed into applied, useful technology is seldom fulfilled.

There are also problems in the demand for technology and innovation. In the post-war period, and up to the 1980s, the prevailing view in Latin America was that it was necessary for governments to protect the region's infant industries and support the development of local technology to allow them to grow. This policy, known as "import substitution", was preached by economists from the United Nations Economic Commission for Latin America (ECLAC/CEPAL), and inspired the work of the Argentinean economist Raul Prebisch (Prebisch 1981). To some extent, Brazil, more than other countries in the region, tried to follow these recom-

mendations. The most ambitious project in this area was the market protection policy for microcomputers, but it also included the establishment of research centers associated to state-controlled companies, partnerships between public companies and universities (as between Telebrás, the communications holding company, and Campinas University), and large projects in the areas of atomic energy and space. In the eighties, high inflation, fiscal imbalances and external shocks forced the countries to open their economies and privatize the state-owned companies. The market protection policy for microcomputers was interrupted, and privatized companies cancelled their cooperation agreements with universities and shut or scaled down their research departments (Adler 1987; Baer and Samuelson 1977; Botelho and Smith 1985; Schmitz and Cassiolato 1992; Sutz 1997; Sutz 2000; Vessuri 1990)

There is an on-going argument about whether the import substitution policies could have succeeded in the long run, or were doomed to failure from the beginning, and whether the Asian model, of strong public support for a market oriented, internationally competitive economy would not have been more successful (Amsden 2004; Castro and Souza 1985; Dahlman and Sercovich 1984; Dedrick et al. 2001; Michell 1988; Tigre and Botelho 2001) Even at its best, the links between government, industries and the research institutions in Latin America was limited to a few sectors and a small number of large companies. With the opening of the economy, local companies were forced to compete in the international market, creating a new challenge and a new opportunity for the scientific institutions to increase their links with the production sector. However, privatization and internationalization also meant that many local companies were absorbed by multinational corporations which had their research and development work done elsewhere, while financial restrictions reduced the governments' ability to support long-term innovation projects. For the scientists and their institutions, the alternative was to keep being subsidized with dwindling resources, or move more aggressively to get their resources in the market (Vessuri 1995).

## THE LESSONS FROM POSITIVE EXPERIENCES

In spite of these difficulties, our research shows that, in all countries being studied, several research teams were able to reach out and make important contributions to society, while keeping the academic quality of their work. In doing so, they obtained resources and created a rich and stimulating environment for their researchers and graduate students. These research teams are not representative of the average university research sectors in their countries, but showcases that demonstrate that it is possible to overcome the usual constraints of internal "mode I" culture.

All research groups had to deal, in one way or another, with three central issues – the nature and availability of resources for research support; the tensions between academic careers and scientific and technological entrepreneurship; and the tension between the production of knowledge for the open scientific community and the appropriation of knowledge as patents or other forms of intellectual property. These three dimensions are explored in detail in this volume by Antônio Botelho

and Pimenta Bueno, Elizabeth Balbachevsky and Carlos Correa. They are part of the constraints that are external to the research groups, which have to react and adapt to them differently in each country.

Regardless of the large differences among countries and fields of knowledge, it is possible to state that all the groups studied share some common characteristics. First, by virtue or necessity, they had to move away from the conventional pattern of academic research, and reach out to society and the business sector for support. In Brazil, private institutions, such as the Catholic University and the Getúlio Vargas Foundation in Rio, have no independent means to support advanced research with their own resources; in Argentina and Chile, even the best public institutions do not get full support for their work, and have to develop a strong entrepreneurial culture to function. Public research institutions in Brazil and Mexico are much more likely to obtain strong support and high salaries for their researchers, but, even so, several research groups, such as the Chemistry group in Campinas, or the Unidad Iraupuato of CINVESTAV, in Mexico, developed strong cultures of making their work relevant to industry and society, and bringing additional resources to that which they could obtain from regular sources of support.

A second common feature is that they all had to deal with the norms and regulations of the larger institution to which they belong, usually the central administration at the universities. For the institution, these active research centers are an important asset, bringing prestige, recognition and support to their alma mater, and additional resources. At the same time, they tend to be different from other departments and research centers, do not adapt easily to across-the-board rules and regulations, and, in many cases, their researchers enjoy better working conditions and higher income than others formally in the same situation. To deal with research groups like this, the universities have to be flexible and more concerned with the performance of their units than with their formal procedures and bureaucratic norms. This is not very frequent in Latin America, however, not just because of the tradition of formalism and bureaucratic administration, but also because these formalities often hide ingrained conflicts of values and jealousy among different sectors and groups.

A third common characteristic is that most of the groups had a leading figure that embodied a sense of mission and was able not only to establish high standards for research, but could also establish effective links with the outside world, with government agencies, the business sector, and international agencies and scientific and technical communities. This combination of academic excellence and entrepreneurial prowess is not an anomaly, but, in fact, a common element in most successful research teams and institutions anywhere, as well described in a classic text by Bruno Latour (Latour 1987). The positive role these leaders can perform do not require further elaboration; there is, however, the downside, which is when the leader needs to be replaced, and has not groomed a successor nor created the institutional conditions for sustained work, a transition that many research groups and institutions are unable to handle.

Finally, a fourth common element is the presence of multiple outside clients. In some cases, however, such as the Computer Science Department of the Catholic

University in Rio de Janeiro, there is just one major client, Petrobras, which creates two risks. First, the research group may become too dependent on a partner over which it has no control, and may have difficulty surviving if the partnership ends for some reason; and second that the partner, particularly if it is a public company or institution, can become, in practice, a supplier of funds, rather than active user of the knowledge produced by the research group. The best arrangement, not always easy to obtain, is to work with multiple clients, responding to actual demands for knowledge, instead of relying on a single source. This can be achieved, in some cases, with the support of a major external client at first, and a clear pattern of differentiation later on.

The main question is whether, in the future, these localized experiences can become the norm rather than the exception, and help to shape and make broad, "top down" policies that are closer to the actual behavior and experiences of the leading research groups, and could make science more relevant for Latin American societies. There are reasons for hope, since the need is clear, and many research groups and institutions are already finding their ways and being better rewarded for their achievements, both in terns of resources and recognition. We hope that the evidence, the experiences and the analyses reported in this study can help to accelerate this trend.

## NOTES

[1] For Brazil, we did not deal with the distinction between federal and state public universities, and our two public institution cases are from the University of São Paulo, the country´s largest research university.

[2] The notion of the "research unit", not the individual researcher or the institution, as the basic social component of scientific work was adopted by the UNESCO International Comparative Study of Research Units (ICSOPRU) surveys in the 1980s (Andrews 1979; Schwartzman 1985a; Schwartzman 1985b; Stolte-Heiskanen 1979). What a "research unit" actually is, however, varies among disciplines, institutions and points in time.

[3] Such as the Conselho Nacional de Pesquisas, CNPq, in Brazil, 1951, changed to Conselho Nacional de Desenvolvimento Científico e Tecnológico in 1978; the Consejo Nacional de Investigaciones Científicas y Técnicas, CONICET, in Argentina, 1958; the Comisión Nacional de Investigación Científica y Tecnológica, CONICYT, in Chile, 1967; and the Consejo Nacional de Ciencia y Tecnología, CONACYT, in Mexico, 1970.

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